Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Update to Parts 2 and 25 Concerning Non-Geostationary, Fixed-Satellite Service Systems and Related Matters	)	IB Docket No. 16-408
	)	

COMMENTS OF TELESAT CANADA

TELESAT CANADA
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Telesat Canada ("Telesat") hereby comments on the Notice of Proposed Rulemaking in the above-captioned proceeding (the "NPRM").[1] While Telesat has participated in the development of the comments of the Satellite Industry Association, it is submitting these separate comments to highlight several issues that are of utmost importance.

I. INTRODUCTION AND SUMMARY

Telesat is one of the largest and most successful satellite operators in the world and a leading provider of voice, data, video and IP networking services to the private sector and governments. The company's advanced communications are delivered through its global fleet of 15 satellites, with an additional two geostationary satellite orbit ("GSO") and two non-geostationary satellite orbit ("NGSO") satellites under construction. Telesat also operates a global teleport and terrestrial infrastructure that is integrated with its fleet. Through this combination of space and ground assets, Telesat's communications solutions support the demanding requirements of customers throughout the world.

[1] *Update to Parts 2 and 25 Concerning Non-Geostationary, Fixed-Satellite Service Systems and Related Matters,* Notice of Proposed Rulemaking, IB Docket No. 16-408, FCC 16-170 (rel. Dec. 15, 2016) ("*NPRM*").

Telesat is developing an NGSO low earth orbit ("LEO") constellation comprised of over 100 advanced satellites that will deliver high capacity, high speed, low latency data services with a distributed space architecture designed to enhance network security and resiliency and the ability to provide coverage anywhere in the world. The innovative design combines polar and inclined orbits, incorporates advanced technologies and will operate on almost 4 GHz of Ka-band spectrum. Innovation, Science and Economic Development Canada (formerly Industry Canada) has authorized Telesat to launch and operate this NGSO constellation and Telesat has filed a Petition for Declaratory Ruling with the Commission seeking authority to use the constellation to serve the U.S. market.[2]

As a company that has committed its future to advancing the availability of broadband service throughout the world, Telesat applauds the Commission's vision in updating, clarifying, and streamlining its rules to facilitate the deployment of advanced NGSO constellations and fixed-satellite service ("FSS") systems, to update its rules governing operation of FSS space stations in geostationary orbit to enable greater operational flexibility and, more generally, recognizing the importance of harmonizing its rules with the regulations of the International Telecommunications Union ("ITU") to facilitate the operation of global satellite constellations and systems. Given recent developments in satellite and launch technology and the surging global demand for high capacity, low latency broadband services, NGSO satellite constellations offer great promise in meeting the Commission's objective to bring state-of-the-art broadband connectivity to unserved and underserved communities. This rulemaking proceeding represents a crucial opportunity to ensure that a regulatory framework is put in place that fosters the substantial investment required to make these advanced NGSO constellations a reality.

[2] Telesat's Petition for Declaratory Ruling, File No. SAT−LOI−20161115−00108 (Nov. 15, 2016).

It is particularly important to harmonize the ITU's and FCC's regulations and coordination procedures concerning interference events among NGSO constellations. The FCC's proposal for addressing interference among NGSO constellations is unworkable for a number of reasons (see below). Adopting the ITU's regulations and coordination procedures would be a better approach.

As detailed below and in Attachment A, the Commission's existing rule, with its 10° default avoidance-angle trigger, is inappropriate as a technical matter. No single avoidance angle accurately defines the angle necessary to prevent harmful interference among systems, because the exact angle will depend on the design of each system and the relative position of satellites and ground stations. Thus, the avoidance angle necessary to prevent harmful interference will vary widely from system to system, and between any two systems it will vary over time and geography.

More fundamentally, as discussed in detail below, there are at least three reasons why a "share during in-line events" rule should not be implemented:

1. It would be impractical to implement a "share during in-line events" rule given the vast amount of sensitive data operators would have to exchange in real time in order for operators to know when an in-line event is about to occur.
2. It would generate uncertainty as to the amount of interference-free spectrum that might be available to an NGSO system at any given time, thereby discouraging the substantial investment necessary to implement NGSO systems.
3. Depending on which and how many of the multiple large constellations that have been proposed are implemented, the frequency and duration of in-line events could be so substantial that applying a "share during in-line events" rule would be

functionally equivalent to band segmentation. Virtually all parties believe band segmentation to be contrary to the public interest in fostering broadband satellite services worldwide.

The public interest would be far better served by adopting a requirement that NGSO FSS systems coordinate their operations in accordance with existing ITU regulations.

Finally, implementation of the Commission's proposals for increasing the availability of Ka-band frequencies for NGSO systems and reforming its process rules regarding deployment milestones and bond requirements will enhance NGSO FSS operational flexibility and facilitate system implementation and management.

II. COMMISSION RULES GOVERNING NGSO AND GSO FSS SYSTEMS SHOULD BE HARMONIZED WITH ITU RULES

Most NGSO FSS networks and many GSO FSS networks are designed to cover large territorial expanses and serve multiple regions of the world, not only the United States. Satellite network operators must comply with limits and other rules contained in the ITU Radio Regulations, as well as with the rules of the administrations in whose territories they operate. Designing and operating international satellite systems to conform to a wide variety of different rules at different locations can be cumbersome, at best, and at times can lead to inefficient solutions and costly implementation. Therefore, harmonization of national rules to the widely-applicable ITU rules is good practice and should be done absent a compelling reason to do otherwise.

In this regard, Telesat supports applying ITU PFD limits to a new FSS allocation in the 17.8 – 18.3 GHz band[3] and extending the applicability of Section 25.208 (c) PFD limits to GSO FSS space stations in the 17.7 – 19.7 GHz bands and to all space stations in the bands 22.55-23.55 GHz and 24.45-24.75 GHz.[4] Telesat also agrees with the Commission that the interference produced by an NGSO FSS constellation to terrestrial stations varies over time and that, accordingly, terrestrial stations would be better protected by EPFD limits, rather than PFD limits.[5]

However, the EPFD limits contained in Article 22 of the ITU Radio Regulations cannot be applied directly to protect terrestrial stations. These EPFD limits were adopted to protect GSO FSS networks and are based upon reference antenna patterns and geometry applicable to the GSO FSS. Receivers in the GSO FSS are located either on the geostationary arc or at satellite earth stations facing that arc. In contrast, terrestrial receivers may be oriented in any azimuth and through a range of elevations. The development of appropriate EPFD limits to protect terrestrial services, therefore, will require the adoption both of a suitable fixed-service reference antenna pattern and an assumed off-axis discrimination to be used in the calculations. Pending the development of such EPFD limits, Telesat supports the Commission's alternative proposal to apply an interim limit on aggregate PFD of -115 (dBW/m^2)/MHz produced by a whole NGSO constellation at any point on the earth's surface.[6]

[3] NPRM at 9

[4] NPRM at 15

[5] NPRM at 16

[6] *Id.*

Similarly, as a longstanding GSO FSS operator, Telesat strongly supports the Commission's proposal to apply ITU limits to protect the GSO FSS from possible interference from NGSO FSS systems. Accordingly, NGSO applicants should be required to comply with the ITU Article 22 EPFD limits. Similarly, Telesat supports the Commission's proposal to incorporate ITU EPFD limits in applicable bands on inter-satellite emissions into the Commission's Rules.[7] Telesat also supports the Commission's proposal to adopt a default sharing mechanism analogous to provision 22.2 of the ITU Radio Regulations, whereby unless otherwise provided in the Commission's Rules, NGSO FSS systems must not cause harmful interference to, or claim protection from, GSO FSS and GSO BSS networks.

The EPFD limits in Article 22 of the ITU Radio Regulations, when adopted by the Commission, will go a long way to foster spectrum efficiency and more effective sharing of spectrum resources between GSO and NGSO international satellite systems.

III. THE COMMISSION SHOULD APPLY ITU COORDINATION REQUIREMENTS TO NGSO FSS SYSTEMS IN LIEU OF OTHER IN-LINE EVENT INTERFERENCE MITIGATION RULES

A. Overview

Innovative NGSO systems offer tremendous promise to provide high capacity, low-latency broadband services to many unserved and underserved areas around the world, including residents of vast areas of rural America, tribal lands, and other communities. These systems also will meet the important requirements of U.S. government users, who are calling for more resilient, distributed and secure space-based networks in an increasingly congested, contested and competitive space environment. But the cost of such systems, whether Telesat's or others',

[7] NPRM at 19

is significant, often in the billions of dollars. To support such investment, systems need access to all authorized spectrum, not just portions of it, as the cost per bit skyrockets as available spectrum is decreased. Those making such investment also require certainty that their access to spectrum will not be jeopardized as new systems are launched and that, throughout the life of their systems, they will be protected from harmful interference.

Telesat demonstrates below that a "default mechanism" like the one set out in the Commission's Rules to enable spectrum sharing among NGSO FSS systems in certain frequency bands does not serve these requirements. Neither the default angle specified in the rules—10 degrees—nor any other single angle can be specified that would adequately define the avoidance angle required between any two systems to avoid harmful interference. The complex geometry of using avoidance angle triggers for in-line events is shown graphically in Attachment A. As demonstrated therein, a single, universally-applied trigger angle cannot work because the trigger angle will vary widely on both the uplink and downlink as a function of the system parameters involved. Not only does the angle vary among different constellations, but between any two constellations the angle will vary based on the relative position of satellites to ground terminals. Thus, while the Commission seeks comment as to whether the avoidance-angle trigger should be increased or decreased to reflect current system designs,[8] the problem cannot be solved by changing to a different, single angle.

The problems with a "share during in-line events" rule are much more fundamental, however, than the fact that there is no single trigger angle that will adequately and effectively protect NGSO systems from harmful interference: the fundamental problem is that, as discussed in more detail below, the Commission's current "default rule" is now outdated and inappropriate

[8] NPRM at ¶ 26

to state-of-the-art NGSO FSS constellations. As the Commission itself has noted, the rule was adopted in an era with fewer and simpler constellations and is premised on the assumption that the rule will allow all authorized NGSO FSS systems to operate simultaneously in their authorized band most of the time, except in limited circumstances when an "in-line interference event" would require them to divide commonly-assigned spectrum equally, absent a coordination arrangement between them. These premises do not comport with the reality of current NGSO FSS constellation system design nor the fact that user terminals supported by these systems will be increasingly mobile in nature.[9]

For an avoidance angle rule to be implemented, the operators of competing systems would have to know the location, operation, and intended transmission time of every earth station (many of which will be mobile) and satellite of every other NGSO constellation system authorized in the same band—particularly difficult in light of the highly dynamic nature in which these systems are envisioned to operate—then to factor such operational information into the determination of its own network operations, all in real time. Putting aside the competitive concerns associated with the sharing of such information, the systems would themselves need to be interoperable, which would be simply unrealistic to implement.

Moreover, under such a regime, how much spectrum any individual system might have available to it would be unknown: it would be dependent on the number, design, and implementation, both as to satellites and ground networks, of other NGSO operators. The prospect of continuing uncertainty about the availability of sufficient operating spectrum would

[9] The FCC's Rules do not authorize NGSO satellites to serve mobile terminals in the Ku-band or the Ka-band. Such terminals could be used in the United States only on a waiver basis. A number of applicants in the Ku/Ka-band NGSO processing round have proposed to serve mobile terminals.

discourage the massive investments required to construct and launch NGSO systems. Perversely, those operators planning the most investment in innovative designs and full broadband coverage, best to serve the public and government users, might be the first to decide not to proceed.

Finally, given the potential for a multitude of satellites, beams, and earth stations operational at different times and changing over time, there is a real risk that this so-called "default" mechanism of band sharing would have to be employed a substantial amount of the time, rather than from time to time. This would be functionally equivalent to band segmentation. Virtually everyone agrees that band segmentation could leave every system with insufficient bandwidth, which would undercut the Commission's goal of facilitating a viable broadband service.

Fortunately, there is an effective alternative: coordination as already required under ITU regulations. That coordination mechanism has served the GSO world well and also would work well for NGSO systems. In each case, in addition to establishing a clearly understood process for coordination, application of the ITU rules will allow systems the necessary certainty as to the availability of spectrum free from harmful interference. Application of the ITU rules also would allow operators the benefit of being able to design their systems and to operate under a single set of rules, uniform across regions.

B. No Single Avoidance Angle Will Avoid In-line Interference Events

There is no "one-size-fits-all" angle for determining in-line interference events. As demonstrated in Attachment A, defining a default avoidance angle, whether 10° or some other generally-applied value, is not workable because the in-line event avoidance angle is a function of the design parameters of the constellations themselves and, as a result, they vary widely on both the uplink and downlink. The allowable downlink interference level, and hence the

required avoidance angle, is a function of many variables in system parameters: the interfering satellite EIRP, bandwidth, and altitude; the relative position of the satellites to each other and the relevant ground terminals; as well as the interference tolerance in the link budget and the off-axis gain pattern of the terminal receiving the interference. Similar considerations apply on the uplink.

As a consequence, a single, universally-applied trigger angle cannot work because the trigger angle will vary widely on both the uplink and downlink as a function of the system parameters involved and the relative position of satellites to ground terminals. Thus, a single angle cannot be set even between two constellations, let alone for all constellations.

C. The "Share During In-Line Events" Rule Was Adopted Based on Circumstances that No Longer Apply

The Commission itself raises questions in the NPRM regarding the continued efficacy of its current in-line interference default sharing rules in light of the changes that have been made in the design of satellite systems since the rules were adopted. The Commission notes, in asking for comment regarding the 10° avoidance angle, that this standard is "based on the characteristics of satellite systems proposed around the turn of the millennium" so may need to be changed.[10] As noted above, however, the problem goes beyond merely tinkering with the avoidance angle trigger. The state-of-the-art NGSO systems now being planned are both qualitatively and quantitatively different from those the Commission had before it in 2003, when the current rules were adopted. Further, the thousands of satellites proposed, even within a single constellation, dwarf the systems under consideration in 2003.

[10] NPRM at ¶ 26

Of note, in the Commission's *2003 Order* that adopted the current rules, the Commission pointed to the fact that Teledesic had reduced the number of satellites in its proposed constellation from 288 to 30 thereby making it easier for the rule to be implemented. The Commission stated that, as a result, the "reduced level of complex coordination in this band further limits the need to develop and maintain an intricate set of inter-system coordination priorities among operators in this band."[11] The Commission assessed that, even with all proposed systems implemented, "in-line interference events will occur in a small number of the annual operating hours of these systems."[12] Further, while indicating an expectation that the rules would be workable for future NGSO systems, the Commission limited the sharing procedures it adopted in the *2003 Order* to just the five systems before it.[13]

D. Implementing a "Share During In-Line Events" Requirement Is No Longer Workable

With the new, larger and more complex constellations, and with what is likely to be a significant percentage of mobile terminals, what operators would need to do to be able to implement a "share during in-line events" rule, separate and apart from the impacts of such a rule, would be complex to the point of not being feasible. Determining when in-line events will occur would require each operator to know the location, operation, and intended transmission time of every earth station and satellite of every other NGSO constellation system authorized in

[11] *Report and Order, In the Matter of The Establishment of Policies and Service Rules for the Non-Geostationary Satellite Orbit, Fixed Satellite Service in the Ka-Band*, 18 FCC Rcd 14708, ¶ 26 (2003)("*2003 Order*") .

[12] *2003 Order*, 18 FCC Rcd. at ¶37.

[13] *2003 Order*, 18 FCC Rcd. at ¶ 1.

the same band, then to factor such operational information into the determination of its own network operations, all in real time.

For currently-proposed systems, that would be a constantly moving target, both as to the location of earth stations—with large number of user terminals, many of which will be mobile, and with the frequent addition and subtraction of fixed terminals to and from the networks—and as to which earth stations may be communicating with the satellite at any given time. That information also would be highly sensitive commercially —essentially providing the customer base and usage characteristics of the system. Even if system operators were willing to disclose such information to their competitors, implementing this disclosure would necessitate establishing communications links between and among their operations support systems.

Even if all these hurdles could be overcome, attempting to implement a "share during in-line events" regime would involve layers of complexity that are not even considered in the NPRM. There would be a daisy chain effect of potential interference events, involving multiple constellations and multiple satellites and associated earth stations, not each directly interfering with all at the same instant, but with inter-related effects, at particular points in times and locations: the operation of system "A" could interfere with systems "B" and "D", not "C", but "B" could interfere with "C" but not "D", and so on. To say the least, the "daisy chain" would make it difficult even to determine how the band should be split during such events. Accordingly, implementing a rule that is premised on sharing of spectrum during in-line events, however defined, is impractical.

E. A "Share during In-Line Events" Regime Would Result in Uncertainty as to the Amount of Available Spectrum, Which Would Discourage Investment in the Very Systems for Which There Is the Most Public Need

The degree to which systems would suffer in-line interference from other systems is dependent upon the system design and operation of other systems and will vary by system. Thus, the amount of spectrum an operator will lose access to, and hence the amount of capacity the operator will no longer be able to make available to its customers, will depend on the characteristics of the other constellations operating in the same frequency band.

These characteristics would change over time. For example, in the current Ku/Ka-band processing round,[14] twelve applications with widely varying system designs have been submitted. It cannot be determined in advance which constellations actually will be built, when and in what planes satellites actually will be deployed, when and where earth stations will be made operational, and whether the technical parameters will remain as filed or be modified. Nor can it be known if new parties will file outside of the present processing round.

Uncertainty as to how much interference-free spectrum would be available for any individual system could be a death knell for the enormous investment necessary to implement the kind of broadband services necessary to bridge the digital divide and meet the requirements of government users. The prospect that available spectrum might be substantially reduced as other systems are implemented puts those wishing to make the investment in innovative broadband service in an untenable position. Business plans based upon a projected system capacity and cost

[14] *See Public Notice, OneWeb Petition Accepted for Filing,* DA 16-804, File No. SAT-LOI-20160428-00041 (July 15, 2016), announcing current processing round.

per bit – among the most consequential assumptions in business plans of this nature – go out the window if the amount of capacity that will be available to a system are unknown.

F. A "Share during In-Line Events" Regime Could Be Functionally Equivalent to Band Segmentation

Given the potential for a multitude of satellites, beams, and earth stations operational at different times and changing over time, it is no longer the case, as the Commission assumed when it adopted the current rule, that "in-line interference events will occur in a small number of the annual operating hours of these systems."[15] Rather, there is a real risk that in-line events would occur a substantial amount of the time. If in-line events occur a substantial amount of the time and the Commission mandates sharing during in-line events, then the Commission would be establishing a regime that is functionally equivalent to band segmentation. Virtually everyone agrees, however, that band segmentation would be the wrong approach. It would leave every system with insufficient bandwidth, which would undercut the Commission's goal of facilitating a viable broadband service. To avoid these adverse consequences, a different approach is required.

G. The Commission Should Apply ITU Coordination Requirements to Sharing among NGSO FSS Systems

The ITU already has regulations in place that govern sharing, based on coordination, among NGSO FSS systems in the Ku-band and the Ka-band. The FCC should condition NGSO FSS grants on inter-system coordination in accordance with these ITU regulations, as it does with GSO grants.[16] ITU priority rules work to allow systems certainty as to the amount of

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[16] *See* 47 C.F.R. § 25.111(b).

spectrum that will be available for their systems, while at the same time provide for coordination arrangements to be made to accommodate later entrants. This regulatory system provides those willing to make the substantial investment that will be required to implement an NGSO FSS system of the scope required effectively to serve U.S. and worldwide broadband requirements the necessary certainty that sufficient spectrum, free from harmful interference, will be available.

A further significant benefit of harmonizing FCC requirements with ITU coordination requirements would be that it would be permit system operators to function under a single set of rules. Otherwise, NGSO operators would be transmitting to earth stations in the United States based on one set of rules and to earth stations outside the United States based on a different set of rules.

Under ITU procedures, details of the sharing process between two satellite systems, including matters of the avoidance angles needed to prevent interference between those systems, would be included in a coordination agreement. In the event that no coordination agreement had been reached, the operator having the lower ITU network priority would be required to avoid harmful interference to a network having higher ITU priority. This process would apply among networks licensed by the Commission or granted market access to the U.S., whether they were filed as part of the same processing round or at different times.

IV. THE COMMISSION SHOULD ALLOW GREATER FLEXIBILITY IN NGSO FSS OPERATIONS AND FACILITATE SYSTEM IMPLEMENTATION AND MANAGEMENT

The NPRM contains a number of proposed changes to the Commission's Rules that would permit greater flexibility in NGSO FSS operations while at the same time facilitating system implementation and management of multiple systems operating in the same spectrum and

in increasingly crowded orbital space. In particular, Telesat supports the Commission's proposal to create a new FSS allocation in the 17.8 – 18.3 GHz band subject to provisions to protect primary FS stations and secondary GSO FSS networks.[17] Telesat notes that such operation has been granted previously by waiver and believes codification as a new allocation is desirable.

In addition, permitting NGSO FSS networks to operate in the 18.3 – 18.6 GHz and 19.7 – 20.2 GHz bands on an unprotected, non-interference basis with respect to GSO FSS networks will increase system operators' flexibility in managing their networks and will lead to greater efficiencies in spectrum use.

Telesat further supports the Commission's proposal to require NGSO FSS operators, whether licensed by the U.S. or granted U.S. market access, to share ephemeris data for satellites in their constellations. [18] Such sharing of data is necessary to minimize the risk of collision and creation of orbital debris. With a large number of LEO/MEO/HEO satellite constellations being planned, it will be important to regulate ephemeris data accuracy and availability. Telesat is open to either an electronic bulletin board or an organization such as the U.S. Strategic Command's Joint Space Operations Center (JSpOC) maintaining a Master Database accessible on a confidential basis to all NGSO operators in a standard format. Telesat recommends, however, that such data not be made available to the general public for security reasons.

As conjunction analysis requires further processing and analysis of the data, it would be preferable if such data was provided by all to a competent organization (*e.g.*, JSpOC) which could then disseminate such data to all affected parties. Moreover, NGSO satellite operators

[17] NPRM at ¶ 9

[18] NPRM at ¶ 24

should continue to update complete ephemeris data every three days at a minimum, unless a substantial orbit deviation occurs (*e.g.*, 1 km) for any NGSO satellite. In this case, ephemeris data should be updated immediately.

The Commission also sought comment on adopting EIRP density limits for NGSO FSS uplink transmissions and any other measures that would facilitate sharing.[19] Telesat opposes applying EIRP density limits to NGSO FSS uplink transmissions. For the reasons discussed in Section II of these Comments, ITU coordination requirements should apply to NGSO FSS systems in the Ku-band and the Ka-band. EIRP density limits are unnecessary if ITU coordination requirements are observed.

V. THE COMMISSION SHOULD ENSURE THAT ITS NGSO PROCESSING AND SERVICE RULES FOSTER OPERATIONAL FLEXIBILITY AND SPECTRUM EFFICIENCY

As with the substantive rules discussed above, the Commission should ensure that its own NGSO application processing rules and service rules also serve the interest of NGSO system flexibility and spectrum efficiency, while at the same time promoting the deployment of broadband services to the public. Telesat believes that the Commission's proposals in the NPRM will accomplish these goals.

Telesat agrees with the Commission that its milestone requirements for NGSO systems should be adjusted "[t]o afford operators greater flexibility with system design and implementation."[20]

[19] NPRM at ¶ 30

[20] NPRM at ¶ 32

Given the wide variety of suggested approaches, Telesat recommends that, rather than fixing a standard based upon the number or percentage of satellites launched, the Commission establish the following test: not later than six years from license grant an NGSO licensee must be in commercial service and must be providing a substantial, commercially viable service consistent with that proposed in its application over a substantial portion of the area proposed to be served by its system.

Telesat further urges that, if the Commission decides to modify its milestone requirements, the Commission should give pending NGSO applicants an opportunity to amend their applications to take into account the changes in milestone requirements. In particular, those applicants who may have submitted more conservative proposals in light of current "build all or lose all" rules should have an opportunity to amend their proposals so as to specify a greater number of satellites and orbital planes that would be consistent with their anticipated system expansion over time.

In addition, the Commission should ensure that its rules leave room for NGSO FSS licensees to expand their constellations to satisfy increasing demand. Any expansion should, of course, be consistent with ITU coordination requirements and applicable EPFD limits.

With respect to replacement satellites, satellite network operators are sufficiently motivated to maintain continuity of service; therefore, there is no need to apply milestone and bond-posting requirements to replacement satellites. Telesat welcomes the Commission's clarification that this is the case.

VI. CONCLUSION

In view of the foregoing, the Commission should:

- Harmonize its EPFD limits with ITU requirements in the manner described herein.

- Reject proposals for sharing during in-line events, which

    - Are premised on there being a single, fixed angle for in-line events, when in fact the angle needed to protect systems will vary widely;

    - Are based on the characteristics of early-generation systems and do not take into account the large constellation sizes and designs that are representative of today's systems and the fact that many users of the next generation systems will be mobile;

    - Are unworkable commercially and technically, because the requirements for implementing a regime based on in-line events would be so complex as to be infeasible and would require operators to share commercially-sensitive information;

    - Would create uncertainty as to the spectrum available to an operator and could be the functional equivalent of band segmentation, which virtually everyone agrees would be bad policy;

    - Would discourage investment in the very systems most likely to advance important public interests.

- Adopt Telesat's proposal to apply ITU coordination requirements to sharing among NGSO FSS systems.

- Adopt the proposals addressed herein that would provide for greater flexibility in NGSO FSS operations and facilitate system implementation and management.

- Make the changes addressed herein that would foster operational flexibility and spectrum efficiency.

Respectfully submitted,

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ATTACHMENT A

IN-LINE INTERFERENCE EVENT ANALYSIS

An in-line interference event occurs when there is sufficient physical alignment between the space stations of two different NGSO FSS networks and an operating Earth station of one of those networks, such that:

(1) the space station of one network causes interference to the Earth station intending to communicate with the space station of the other network (downlink interference event); or

(2) the Earth station intending to communicate with a space station of one network causes interference to a space station of the other network (uplink interference event).

The Commission's rules at §25.261 define a procedure for addressing in-line interference events for certain FSS bands. Under §25.261, absent any agreed coordination the frequency bands will be divided among the affected satellite networks; however, operations may resume across the entire bands once the avoidance angle between the affected stations in the in-line interference event is greater than 10°. In this present rulemaking the Commission seeks comment on extending the procedure of §25.261 to other frequency bands[1] and on the value of 10° as the default trigger.[2] The Commission also seeks comment on any other standard for assigning spectrum.[3]

[1] NPRM at ¶ 23

[2] NPRM at ¶26

[3] NPRM at ¶23

The technical showing below details the downlink in-line interference. For illustrative purposes we consider the network characteristics of certain submissions in response to the current Ka-band NGSO processing round. We demonstrate that a fixed avoidance angle, whether 10° or some other value, does not adequately address the range of characteristics associated with the non-GSO constellations being proposed, and that the amount of interference a given system will suffer taking into account a 10° avoidance angle varies widely between systems and also varies as a function of the relative position of the satellites to the earth stations.

The geometry of a downlink in-line interference event is shown in Figure 1 below. Satellites NGSO A and NGSO B are intending to communicate with Earth Stations A and B, respectively. We have assumed Earth Stations A and B are closely located. The figure illustrates that at an angle θ, Earth Station A receives interference from NGSO B.

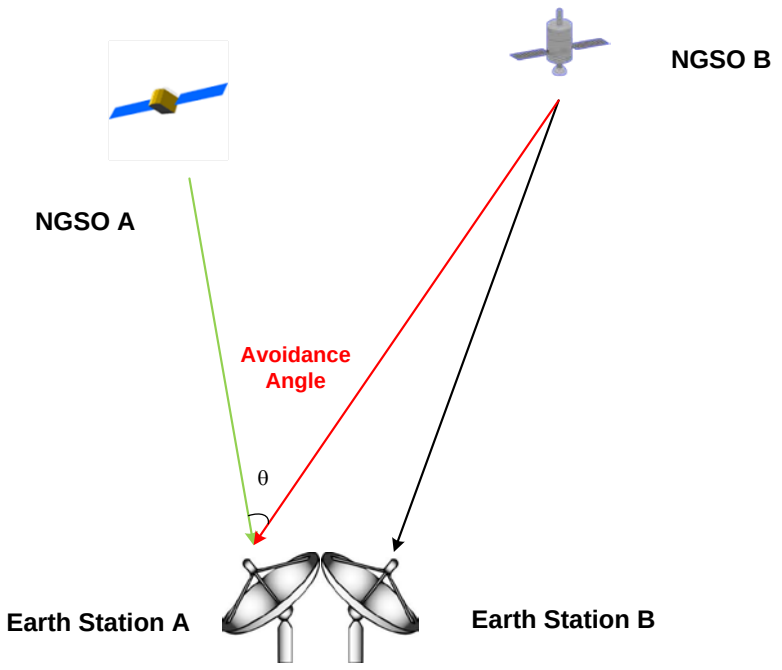

Figure 1 – Downlink In-Line Event Geometry

The interference (*I*) experienced at Earth Station A is a function of the NGSO B transmit EIRP density, the off-axis receive gain pattern of Earth Station A, and the NGSO B distance from Earth Station A.

For example, for an Earth Station with a 1m antenna, the interference level (*I*) experienced at Earth Station A is calculated as

$$I = EIRP_{NGSO\ B} + 10\log\left(\frac{1}{4\pi d^2}\right) + 10log\left(\frac{G_r(\theta)_{1m}}{G_{r\max\ 1m}}\right) \qquad (1)$$

where:

$EIRP_{NGSO\ B}$	(dBW/MHz)	-	EIRP density transmitted by NGSO B
θ	(deg)	-	Off-axis angle from NGSO B in the direction of the Earth Station A
d	(m)	-	Slant range between NGSO B and Earth Station A
$G_r(\theta)_{1m}$	(dB)	-	Receive antenna gain of Earth Station A in the direction of NGSO B using ITU-R Recommendation S.1428-1
$G_{r,max\ 1m}$	(dB)	-	Peak gain of the antenna of Earth Station A

Using the parameters filed by various applicants in the Ka-band processing round and assuming a frequency of 17.8 GHz, the interference level (*I*) for the 10° off-axis angle was then calculated. The results are provided in Table 1. Two cases are reported in Table 1: the satellites are at their respective minimum slant ranges d_1 (i.e. directly above the earth stations so that slant range = altitude), and the satellites are at their respective maximum slant ranges d_2 (calculated based on reported minimum elevation angle for the service).

Table 1
Interference calculated for a 1m Earth Station A due to NGSO B at a 10º off-axis "avoidance angle," for various constellations filed at the FCC

Interfering NGSO B	Altitude (km)	EIRP Density ($EIRP_{NGSO\ B}$) (dBW/MHz)	Fixed Off-axis Avoidance angle θ (deg)	Minimum Slant Range (d_1) (km)	Interference (I) at Earth Station A for range d_1 (dBW/m^2 MHz)	Minimum Elevation Angle (deg)	Maximum Slant Range (d_2) km	Interference (I) at Earth Station A for range d_2 (dBW/m^2 MHz)
LeoSat	1400	15.0	10	1400	-158.1	10	3480	-166.0
O3B	8062	37.5	10	8062	-150.8	5	12411	-154.5
OneWeb	1200	8.0	10	1200	-163.7	15	2762	-171.0
Telesat	1000	10.0	10	1000	-160.2	10	2763	-169.0
Telesat	1248	10.0	10	1248	-162.1	10	3217	-170.3
SpaceX	1150	15.6	10	1150	-155.8	40	1627	-158.8
Viasat	8200	36.0	10	8200	-152.4	25	10688	-154.7

The results in Table 1 show that with a fixed avoidance angle θ, in this case 10°, a wide variety of interference levels at Earth Station A from NGSO B would be "permitted" under §25.261 as meeting the criterion. For relative orientations of the satellites to the earth station between these two cases set forth above, the permitted interference will fall between the amount of interference for the minimum and maximum slant angles. Hence, a fixed avoidance angle, even between two specified systems will in some cases not protect from interference, and in other cases will require spectrum sharing for a longer duration than necessary to avoid interference.

Similarly, a technical analysis of interference in the uplink direction shows that the amount of interference to a satellite of one constellation from the earth station of another constellation will depend on the transmit characteristics of that interfering earth station, and the relative geometries of the satellites. Therefore, as in the downlink case, there is no single avoidance angle that could be applied to ensure adequate protection from uplink interference.

A more appropriate criterion for determining the point at which harmful interference must be avoided would be a predefined interference trigger. Using such a fixed interference

trigger, equation (1) can be rearranged to calculate a resulting avoidance angle θ required to prevent interference at or greater than the fixed level. As the value of θ is dependent on slant range (d), and thus the position of the satellites, as well as the characteristics of the relevant constellation (EIRP, altitude, etc.), the required discrimination angle will vary among constellations, and between two constellations, it will vary as the satellites move through their orbits. Hence, there would be a wide variety of avoidance angles, which further emphasizes the inappropriateness of establishing a fixed avoidance angle, whether it be 10° or any other value.